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(54) Abstract Title
Enhanced power control signalling in a CDMA cellular radio system

(57) A CDMA cellular mobile radio system comprises a base station arranged for two-way communication with a plurality of mobile terminals. When frames need to be divided between data and signal measurement (e.g. before handing off) each slot, which normally contains two data bits, pilot bits and a transmission power control (TPC) bit has at least three and preferably four TPC bits to maintain reliability of the power control during reception of divided frames. The extra TPC bits may be transmitted in place of the usually transmitted transmission format indicator (TFI) bits.

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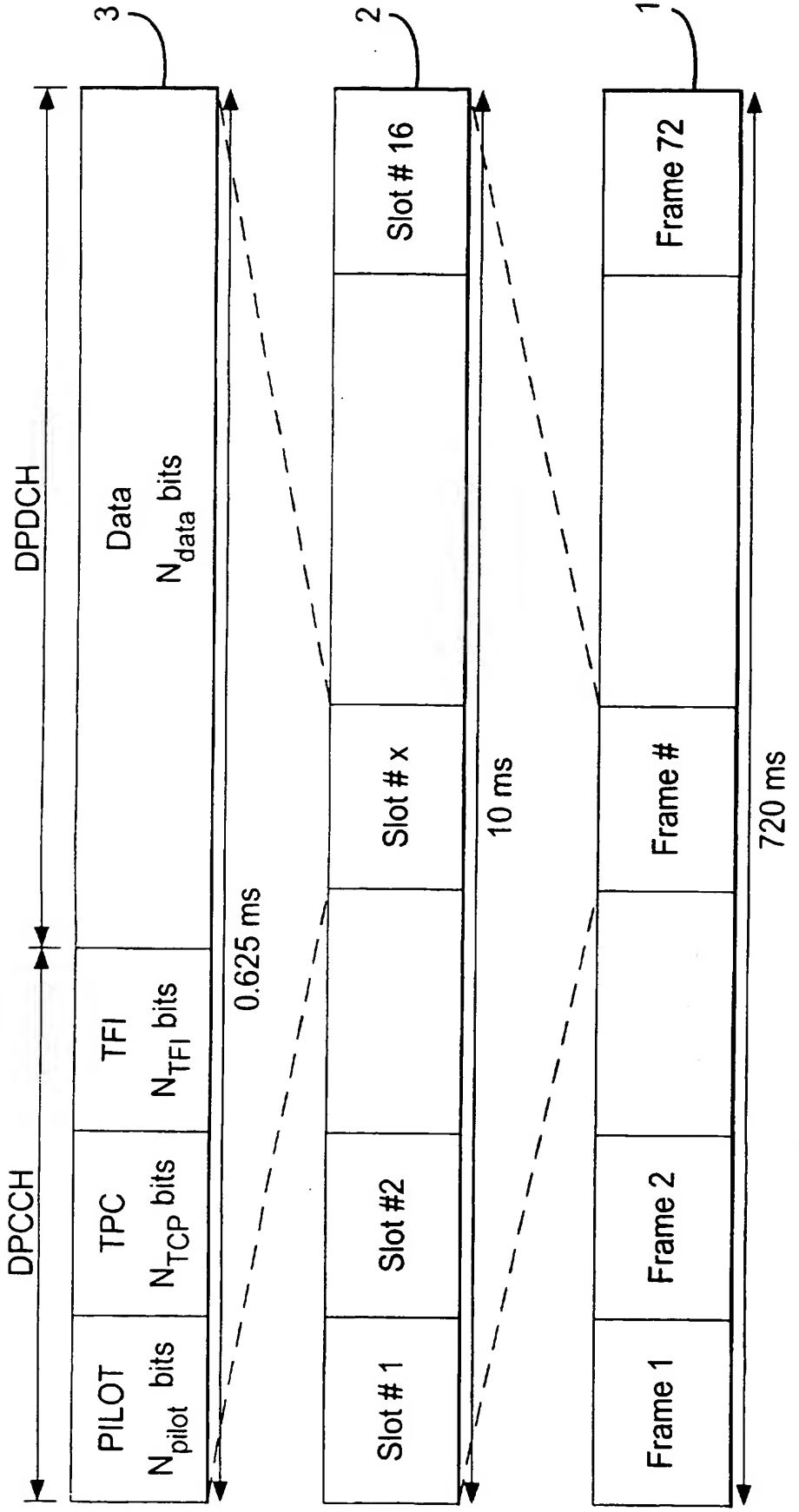

Fig. 1

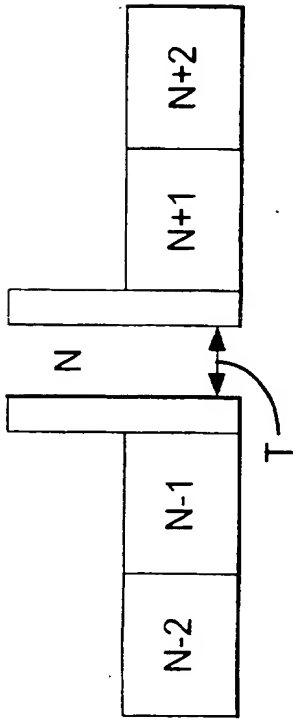

Fig. 2

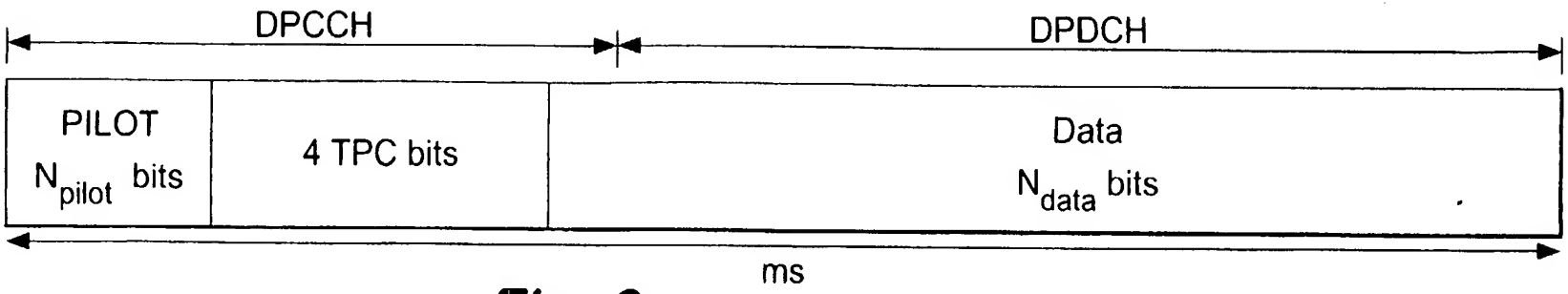

Fig. 3

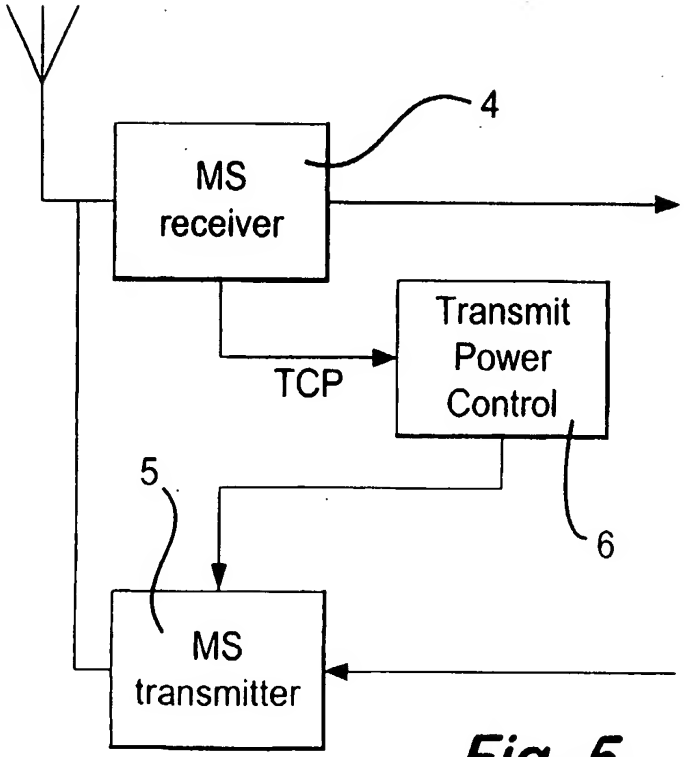

Fig. 5

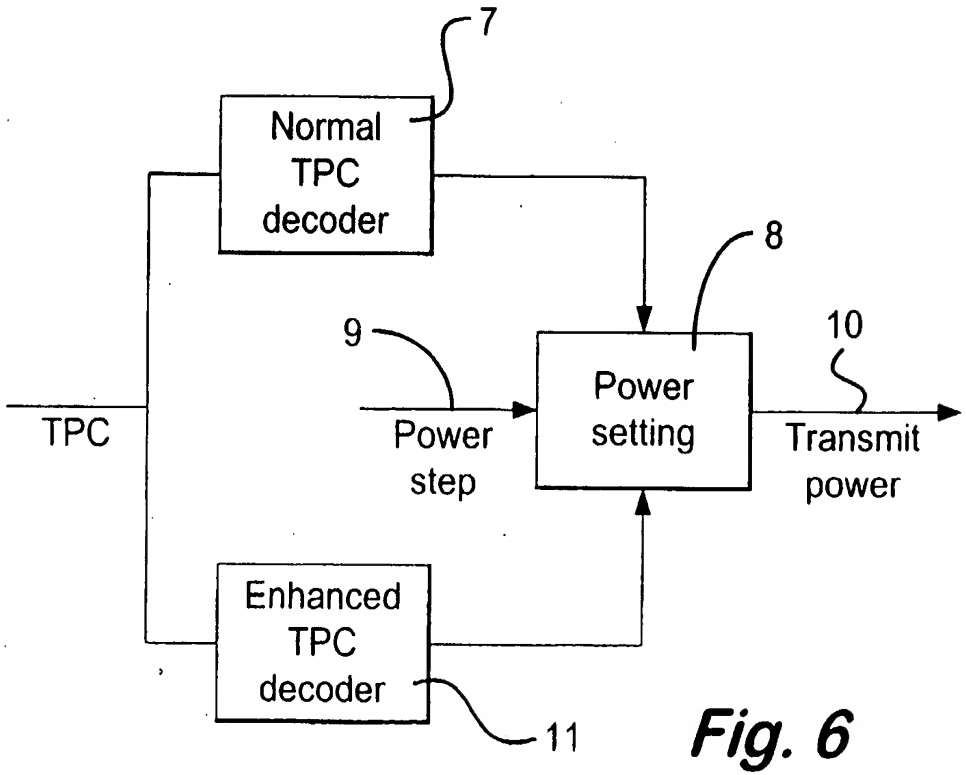

Fig. 6

Fig. 4

Received Bits	Meaning
0000	down more
0001	down
0010	down
0011	nothing
0100	down
0101	nothing
0110	nothing
0111	up
1000	down
1001	nothing
1010	nothing
1011	up
1100	nothing
1101	up
1110	up
1111	up more

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Improvements in or relating cellular to mobile radio systems

This invention relates to cellular mobile radio systems and more especially it relates to Code Division Multiple Access (CDMA) cellular mobile radio systems.

Cellular mobile radio systems comprise a plurality of cells each having a base station which in operation is arranged in two way communication with mobile terminals which are located, at least for the time being, within the cell with which the base station is associated. In known systems, transmissions from a mobile terminal to a base station are described as 'uplink' transmissions and conversely transmissions from a base station to a mobile terminal are described as 'downlink' transmissions. Downlink transmissions in the UTRA FDD system for example, comprise groups of 72 consecutive frames, each of 10 ms duration, wherein each frame comprises 16 consecutive slots which each include pilot bits, 2 Transmission Power Control (TPC) bits, 2 Transmission Format Indicator (TFI) bits, and data bits.

Although each mobile terminal normally communicates with one base station only, in order to facilitate 'hard hand off' to the base station of an adjacent cell as a mobile terminal changes location, or to effect a channel frequency change, provision is made in mobile radio system protocol for dividing a downlink frame in order to provide at the mobile terminal an interval for the measurement of signals from the base station of an adjacent cell. This division of a frame (which is sometimes referred to as 'frame slotting', or 'slotted mode frame operation', and which will herein be described as 'frame division' to avoid terminological confusion), requires compressing a divided frame as necessary in order to accommodate a measurement interval,

or alternatively the deletion of some frame slots, and as specified in the system protocol, the measurement interval may occupy up to 50% of a frame period. One of the problems with frame division is that due to compression, the integrity of the TPC and/or TFI bits may be prejudiced with a consequential signal to noise ratio degradation so that communication may break down or be degraded.

It is an important object of this invention to provide a system which includes frame division without unduly prejudicing the reliability of operation or system performance.

According to the present invention a CDMA cellular mobile radio system comprises a base station arranged for two way communication with a plurality of mobile terminals wherein provision is made for frame division and wherein slots which comprise a divided frame each include pilot bits, at least 3 TPC bits and data bits and wherein the mobile terminals each include an enhanced TPC decoder responsive to at least 3 TPC bits in dependence upon which mobile terminal transmission power is set during the reception of divided frames.

By transmitting at least 3 TPC bits, and preferably twice the usual number of TPC bits in the slots of a divided frame, e.g. 4 instead of 2, the integrity of the system is preserved as will hereinafter be explained, this doubling of the number of TPC bits being facilitated by deleting the TFI bits, which is possible since the transmission of a divided frame is (in a preferred system) signalled in advance on the downlink by higher layer control data so that its arrival is expected, which may be accompanied by the frame transport format so there is no requirement for TFI bits during divided frames.

It will be apparent that although it is possible to compute the omitted TFI bits in a system according to this invention, the computational load would be such that the use of higher layer control data to provide this information is probably the preferred approach.

The mobile terminals may each comprise two TPC decoders one of which is used to control transmission power during normal undivided frames in response to 2 TPC bits, the other of which being the enhanced TPC decoder responsive to 4 TPC bits.

The coding protocol used may be such that in each 4 bit set, the presence of 3 or 4 bits of one sense is deemed to designate a power increase command, whilst the presence 3 or 4 bits of an opposite sense is deemed to designate a power decrease command, and the presence of the same number of bits of each sense is designated to mean 'nothing'.

Thus in each 4 bit set the presence of 3 or 4 '1' bits may be deemed to designate a power increase command, whilst the presence of 3 or 4 '0' bits may be deemed to designate a power decrease command, whilst the presence of the same number of bits of each sense is designated to mean 'nothing'.

Within this coding protocol, 4 identical bits, '0' or '1' may be deemed to designate either 'power up more' or 'power down more', as the case may be.

One embodiment of the invention will now be described by way of example only with reference to the accompanying drawings in which;

Figure 1 is a diagram showing the frame structure in a known UTRA FDD downlink 'Dedicated Physical Channel' (DPCH);

Figure 2 is a diagram showing the frame structure in a known system as required for frame division in so-called 'mid-slot' mode

(there are also 'end-slot' modes not shown, which are known to the cognoscenti and to which the invention may be applied as will be readily apparent to those skilled in the art);

Figure 3 is diagram showing the structure of a slot of a divided frame as used in a system according to the invention;

Figure 4 is a table showing a command protocol which may be assigned to the slot structure as shown in Figure 3;

Figure 5 is a block circuit diagram of a mobile radio system, and;

Figure 6 is a block circuit diagram of a transmit power control unit for use in the system of Figure 5 and including an enhanced TPC decoder responsive to the slot structure of Figure 3.

Referring now to Figure 1, the downlink transmission signal format in a known CDMA cellular mobile radio system comprises a 72 frame group (1), wherein each frame (2), comprises 16 slots and each slot (3) comprises N pilot bits, 2 TPC bits, 2 TFI bits, and M data bits.

In UTRA FDD an option exists for a mobile terminal to measure other signals (than the currently associated one) by means of frame division as shown in Figure 3, wherein a frame N is divided to provide an interval T, during which a mobile terminal may be arranged to receive other signals (or change frequency), satisfactory signal to noise ratios being maintained by boosting power and lowering processing gain.

During a divided frame, the normal slot-by-slot stream is broken and thus control loops for TPC, automatic gain control (AGC), and automatic frequency control (AFC), must be suspended and re-connected somehow.

One obvious possible solution to such a problem is to provide a 'hold' facility, in appropriate sampled control loops appertaining to the functions concerned, to ride out the gap in transmission. This solution is however, somewhat problematic as channel conditions may change invalidating the held values for APC, AGC, and AFC. The DPCCH in the (assumed) downlink case has some pilot bits, 2 TPC bits and 2 TFI bits.

A divided frame must surely be pre-signalled. If it is not, then pure blind detection may needed. If fewer than 16 slots are available then normal TFI would not work. So the TFI bits would be nugatory in a divided frame and where such a frame consists of fewer than 16 slots, as shown in Figure 3, they may be re-allocated to provide 4 TPC bits. If all 16 slots exist in a divided frame then TFI may not be nugatory and recovering their capacity would be optional though sub-optimum. However if the TFI of the frame is pre-signalled then the capacity normally used by TFI bits may be used for as shown for TPC purposes.

The exact details would depend on how compression is achieved in each case and how this affects the DPCCH.

During a period of up to 10 ms (which corresponds to two halves of a frame put together) the required uplink power level may have moved further than the amount it might move during one slot when the control loop is closed.

Increasing the TPC bits from 2 (signalling) up/down to 4 (signalling a 4-level shift) and possibly increasing the maximum possible Δ_{TPC} may help to mitigate the effects of the gap on power control. Even allocating three bits to TPC may help (though this is difficult as they occur in pairs as QPSK symbols).

The current figures assume an effective 'bit error rate' (BER) of 1% for the decoded TPC bits. Better protection may be achieved combined with double step size as follows.

Coding the TPC bits as 2 information bits transmitted as 4 data bits and treating 00 as 'down' and '11' as up leads to the table as shown in Figure 4 wherein; 'more' indicates an enhanced step, possibly double size; there are six patterns which will decode as 'nothing' (37.5%); there are two patterns which may mean a large change up or down, and in these cases a single bit error will change the meaning to a small change in the correct direction, and a double bit error will cause no change; there are two sets of four patterns (25% each) which decode to a small change in a given direction, and a single bit error in these will decode to a large change in the right direction or a 'nothing' word, and a double bit error may lead to a small change in the wrong direction (which is what the present scheme using 2 TPC bits does).

It will be appreciated that in a system according to the invention, FDD fast power control may be enhanced in order to cope with the gap in control flow which divided frame mode operation causes.

As shown in Figure 5, a CDMA cellular mobile radio terminal comprises a radio receiver (4), a radio transmitter (5), and a transmission power controller (6). As shown in Figure 6, the power controller (6), comprises a normally provided 2 TPC bit decoder (7), responsive to the usual 2 TPC bits during normal undivided frames for operating a transmission power controller (8), so that a transmission signal fed thereto on a line (9) is appropriately attenuated prior to being fed on a line (10), to a transmission antenna (not shown), and an enhanced TPC decoder

(11), responsive to 4 TPC bits in accordance with the protocol as shown in the table of Figure 4, and operative during divided frames only, so that the transmission signal fed to the power controller (8) on the line (9) is appropriately attenuated prior to being fed on the line (10), to the transmission antenna (not shown).

CLAIMS.

1. A CDMA cellular mobile radio system comprising a base station arranged for two way communication with a plurality of mobile terminals wherein provision is made for frame division and wherein slots which comprise a divided frame each include pilot bits, at least 3 TPC bits and data bits and wherein the mobile terminals each include an enhanced TPC decoder responsive to at least 3 TPC bits in dependence upon which mobile terminal transmission power is set during the reception of divided frames.

2. A CDMA cellular mobile radio system comprising a base station arranged for two way communication with a plurality of mobile terminals wherein provision is made for frame division and wherein slots which comprise a divided frame each include pilot bits, 4 TPC bits and data bits and wherein the mobile terminals each include an enhanced TPC decoder responsive to 4 TPC bits in dependence upon which mobile terminal transmission power is set during the reception of divided frames.

3. A CDMA cellular mobile radio system as claimed in Claim 2, wherein the mobile terminals each comprise two TPC decoders one of which is used to control transmission power during normal undivided frames in response to 2 TPC bits, the other of which being the enhanced TPC decoder responsive to at least 3 TPC bits.

4. A CDMA cellular mobile radio system as claimed in Claim 2, wherein the coding protocol used is such that in each 4 bit set, the presence of 3 or 4 bits of one sense is deemed to designate a power increase command, whilst the presence 3 or 4 bits of an opposite

sense is deemed to designate a power decrease command, and the presence of the same number of bits of each sense is designated to mean 'nothing'.

5. A CDMA cellular mobile radio system as claimed in Claim 4, wherein in each 4 bit set, the presence of 3 0r 4 '1' bits is deemed to designate a power increase command, whilst the presence of 3 or 4 '0' bits is deemed to designate a power decrease command, whilst the presence of the same number of bits of each sense is designated to mean 'nothing'.

6. A CDMA cellular mobile radio system as claimed in Claim 4, or Claim 5, wherein 4 identical bits, '0' or '1' are deemed to designate relatively larger step function increases of, either 'power up more', or 'power down more', as the case may be.

7. A CDMA cellular mobile radio system substantially as hereinbefore described with reference to the accompanying drawings.

The Patent Office

INVESTOR IN PEOPLE

Application No: GB 9821321.8 **Examiner:** Nigel Hall
Claims searched: all **Date of search:** 1 February 1999

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.Q): H4L (LDH, LDLS)

Int Cl (Ed.6): H04B 7/005; H04Q 7/32

Other: Online: WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
	NONE	

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Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.